

Cassini RADAR Sequence Design Memo

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- Sequence: s01
- Rev: 000
- Observation Id: PH
- Target Body: Phoebe

1 Introduction

This memo describes the Cassini RADAR activities for the S1 sequence of the Saturn Tour. A sequence design memo provides the science context of the scheduled observations, an overview of the pointing design, and guidelines for preparing the RADAR IEB.

The S1 sequence consists of two RADAR activities. Both are distant scatterometer observations of Phoebe with additional time for radiometer raster scans. These observations will be the only opportunity to collect radar backscatter data from Phoebe. Distant scatterometry observations of the icy satellites are accompanied by radiometer observations. The combination of active and passive data can be used to provide information about surface roughness and dielectric coefficient. These data in combination with data from other instruments may be used to constrain the composition and structure of the body.

The S1 sequence will also serve as an engineering test of RADAR uplink tools prior to the first Titan flyby (Ta).

2 CIMS and Division Summary

The Phoebe flyby is a targetted flyby with a closest approach of 2000 km. The ORS instruments will observe around closest approach, and RADAR will observe both inbound and outbound. The RADAR observation is represented to the project by a set of requests in the Cassini Information Management System (CIMS). The CIMS database contains requests for pointing control, time, and data volume. The CIMS requests show a high-level view of the sequence design. Table 1 shows the CIMS request summary for the RADAR.

The CIMS requests form the basis of a pointing design built using the project pointing design tool (PDT). The details of the pointing design are shown by the PDT plots on the corresponding tour sequence web page. (See <https://cassini.jpl.nasa.gov/radar>.) The RADAR pointing sequence is ultimately combined with pointing sequences from other instruments to make a large merged c-kernel. C-kernels are files containing spacecraft attitude data.

A RADAR tool called RADAR Mapping and Sequencing Software (RMSS) reads the merged c-kernel along with other navigation data files, and uses these data to produce a set of instructions for the RADAR observation. The RADAR instructions are called an Instrument Execution Block (IEB). The IEB is produced by running RMSS with a radar config file that controls the process of generating IEB instructions for different segments of time. These segments of time are called divisions with a particular behavior defined by a set of division keywords in the config file. Table 2 shows a summary of the divisions used in this observation. Subsequent sections will show and discuss the keyword

CIMS ID	Start	End	Duration	Comments
000PH.REUBITS001_RIDER	2004-163T11:03:37	2004-163T15:34:37	04:31:0.0	REU bits
000PH.WARMDAT002_RIDER	2004-163T11:03:37	2004-163T14:03:37	03:00:0.0	Warmup the instrument in an opmode that allows RADAR operation as well as collects RADAR data.
000PH.SCATTRAD001_PRIME	2004-163T14:03:37	2004-163T15:34:37	01:31:0.0	Point -Z axis at target and execute raster scan(s) centered on target. Obtain simultaneous scatterometry and radiometry.
000PH.WARMNODAT004_RIDER	2004-163T18:33:37	2004-163T21:33:37	03:00:0.0	Warmup the instrument in an opmode that allows RADAR operation. But in a telemetry mode that does not allow collection of RADAR data.
000PH.2SCATTRAD001_PRIME	2004-163T21:33:37	2004-164T01:48:37	04:15:0.0	Point -Z axis at target and execute raster scan(s) centered on target. Obtain simultaneous scatterometry and radiometry.
000PH.REUBITS002_RIDER	2004-163T21:33:37	2004-164T01:48:37	04:15:0.0	REU bits

Table 1: PH CIMS Request Sequence

selections made for each division. Each division table shows a set of nominal parameters that are determined by the operating mode (eg., distant scatterometry, SAR low-res inbound). The actual division parameters from the config file are also shown, and any meaningful mismatches are flagged.

3 Warmup - 1st IEB

The two windows of time for RADAR to collect data on Phoebe will be covered by one IEB. A separate IEB is used to cover the warmup period. This unusual arrangement is required because of the live movable block which covers the Phoebe approach time, but not the total warmup time. The radar warmup rider begins at 2004-06-11T11:03:37.000 (-08:29:59.2) and lasts for the standard 03:00:0.0.

The ORS instruments need to have the S&ER-5A telemetry mode to start 6 hours before our warmup begins. Extra engineering data are automatically collected in RADAR telemetry modes and it is wasteful to collect these data outside of the time periods allocated for RADAR. RADAR is not charged for the extra engineering data outside of its allocated time periods, so this is more of an issue for the spacecraft.

The allocated rate is 255.4 bps. The extra engineering pickup will take 227 bps of this, and RADAR was able to negotiate for more data volume during the aftermarket process to observe the radiometer data during warmup. During the warmup, the IEB will be set for slow speed radiometer only data as shown in table 3.

Division	Name	Start	End	Duration	Comments
a	distant_warmup	-8:30:0.0	-5:26:0.0	03:04:0.0	Warmup is in separate IEB
b	distant_radiometer	-5:26:0.0	-4:08:0.0	01:18:0.0	Inbound radiometer scan
c	distant_scatterometer	-4:08:0.0	-4:06:0.0	00:02:0.0	Inbound scatterometer stare (Tone, BIF = 1)
d	distant_scatterometer	-4:06:0.0	-4:00:0.0	00:06:0.0	Inbound scatterometer stare (Tone)
e	radiometer_fill	-4:00:0.0	02:20:0.0	06:20:0.0	ORS observation at Phoebe c/a
f	distant_scatterometer	02:20:0.0	02:24:0.0	00:04:0.0	Outbound scatterometer stare (Chirp, PRF 1)
g	distant_scatterometer	02:24:0.0	02:30:30.0	00:06:30.0	Outbound scatterometer stare (Chirp, PRF 2)
h	distant_scatterometer	02:30:30.0	02:35:30.0	00:05:0.0	Outbound scatterometer stare (Tone)
i	distant_radiometer	02:35:30.0	04:25:0.0	01:49:30.0	Outbound radiometer stare
j	distant_radiometer	04:25:0.0	05:17:0.0	00:52:0.0	Outbound radiometer scans 1 and 2
k	distant_radiometer	05:17:0.0	06:40:0.0	01:23:0.0	Outbound radiometer stare

Table 2: Division summary

Name	Nominal	Actual	Mismatch	Comments
mode	radiometer	radiometer	no	
start_time (min)	varies	-510.0	no	
end_time (min)	varies	-326.0	no	
time_step (s)	varies	1800.0	no	Used by radiometer only modes - saves commands
bem	00100	00100	no	
baq	don't care	5	no	
csr	6	6	no	6 - Radiometer Only Mode
noise_bit_setting	don't care	4	no	
dutycycle	don't care	0.38	no	
prf (KHz)	don't care	1.00	no	
number_of_pulses	don't care	8	no	
n_bursts_in_flight	don't care	1	no	
percent_of_BW	don't care	100.0	no	
auto_rad	on	on	no	
rip (ms)	34.0	34.0	no	
max_data_rate	0.250	0.250	no	Kbps - set for slowest burst period
interleave_flag	off	off	no	
interleave_duration (min)	don't care	10.0	no	

Table 3: PH div_a distant_warmup block

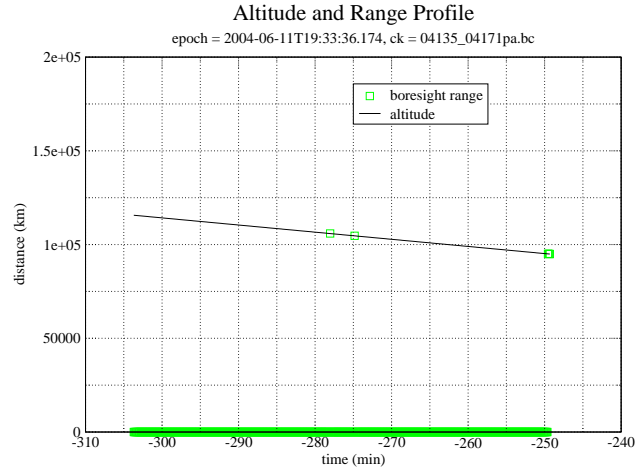


Figure 1: Inbound radiometry: range to target nadir point

4 Inbound Phoebe Distant Scatterometry/Radiometry - 2nd IEB

The inbound observation starts at 2004-06-11T14:03:37.000 (-05:29:59.2) with a duration of 01:31:0.0. This time period is divided into two different radar observations - a radiometry raster scan, followed by a distant scatterometer integration. Integration refers to the accumulation of many pulses to form one image. The recommended pointing strategy is to execute a simple raster scan for radiometry at the beginning, just like other radiometry rasters of icy satellites, then target the center of Phoebe and stare at it for the remainder of the observation. The scatterometer integration is positioned at the end of the staring interval (programmed in the IEB) when the signal is strongest.

The inbound observation is at about twice the range of the outbound observation, and our limited data volume is better spent on the closer observation. Nonetheless, the inbound observation observes a different portion of Phoebe (the only opportunity) so it is still worthwhile to spend some data on the inbound observation. Thus, about 87 Mbits out of the total 287 Mbits is allocated to the first observation.

4.1 Inbound Radiometry - Div B

For the inbound radiometry raster scan, the range variation to the target is shown in Fig. 1. The radiometry scan will consume a minor part of the 87 Mbits allocated to the inbound observation.

Figures 2 and 3 show the pointing design for the radiometry scan from the merged ckernel. The boresight is pointed most of the time off target, hence the range/altitude plot shows only a few boresight range points. The scans use 1/4 beamwidth spacing to allow for some super-resolution processing of the radiometer data. The angular size of the target is about 2.0 mrad during this division. The beam 3 beamwidth is 6 mrad, so radiometer resolution will be limited. The IEB for the inbound radiometry observation is controlled by a standard distant radiometer block as shown in Table 4

4.2 Inbound Scatterometry - Div's C,D

The inbound scatterometry stare is separated into two intervals, division C and division D. Division C is a two minute section with one burst in flight. It is placed as a precaution since the multiple bursts in flight used in subsequent scatterometer divisions are more complex to design. The data rate is low in this division because instrument timing constraints do not allow a very high burst duty cycle to be realized with one burst in flight.

Division D covers the rest of the inbound scatterometer integration. This portion uses multiple bursts in flight to allow a higher PRF and a higher data rate and duty cycle. The range variation to the target during the scatterometer integration is shown in Fig. 4. Most of the remaining 76.2 Mbits will be used here.

Figure 5 shows the pointing design from the merged ckernel. During the implementation of the science operations plan (SOP) for this sequence, the inbound staring time was set to 12 minutes. Division C will use two of those minutes. Using division C's specified maximum rate of 90.0 Kbps, the two minutes will consume 10.8 Mbits. For division D,

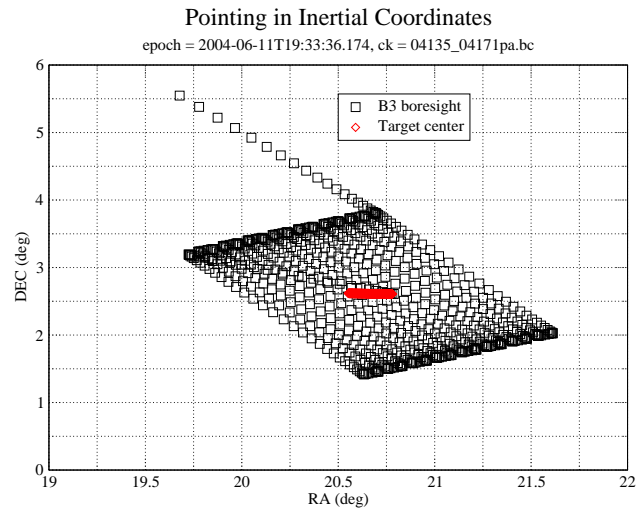


Figure 2: Inbound scan in inertial coordinates

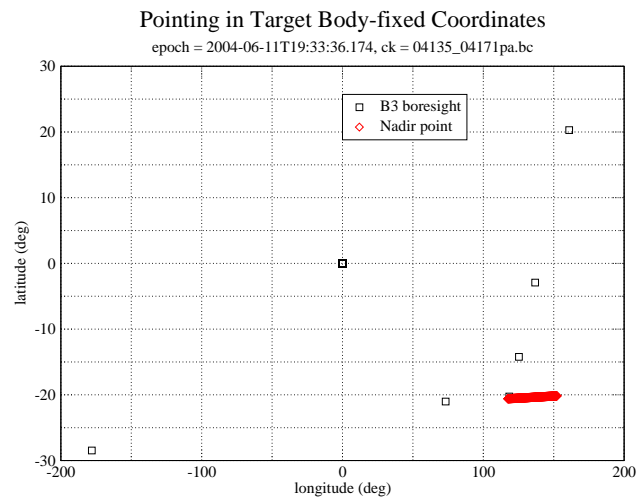


Figure 3: Inbound scan in target body-fixed coordinates

Name	Nominal	Actual	Mismatch	Comments
mode	radiometer	radiometer	no	
start_time (min)	varies	-326.0	no	
end_time (min)	varies	-248.0	no	
time_step (s)	varies	300.0	no	Used by radiometer only modes
bem	00100	00100	no	
baq	don't care	5	no	
csr	6	6	no	
noise_bit_setting	don't care	4	no	
dutycycle	don't care	0.38	no	
prf (KHz)	don't care	1.00	no	
number_of_pulses	don't care	8	no	
n_bursts_in_flight	don't care	1	no	
percent_of_BW	don't care	100.0	no	
auto_rad	on	on	no	
rip (ms)	34.0	34.0	no	starting value for auto-rad
max_data_rate	1.000	1.000	no	1 Kbps - 1 s burst period which is adequate for slow radiometer scans
interleave_flag	off	off	no	
interleave_duration (min)	don't care	10.0	no	

Table 4: PH div_b distant_radiometer block

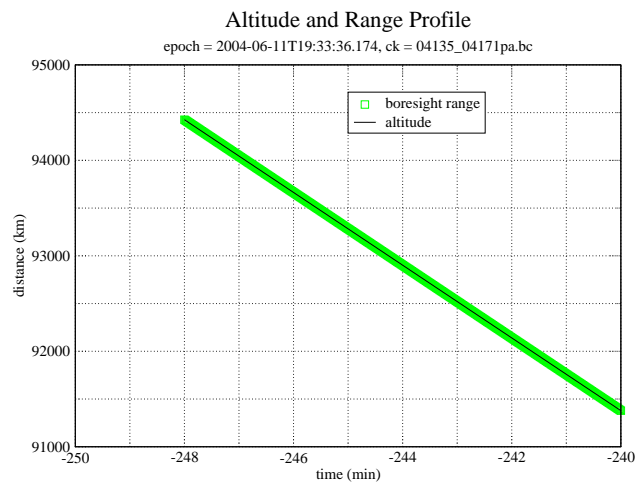


Figure 4: Inbound scatterometry Div's C,D: range to target nadir point

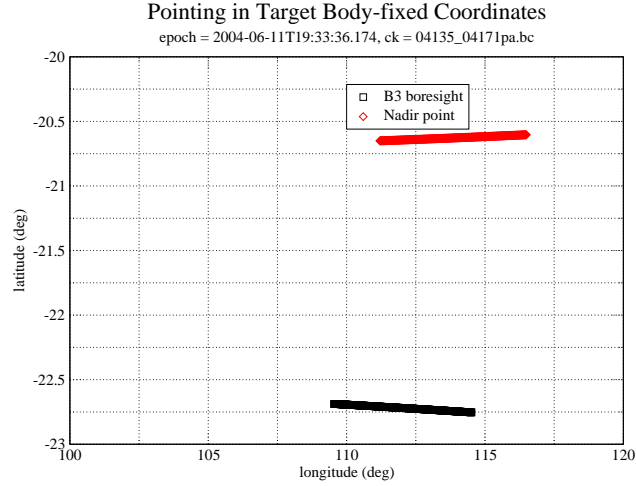


Figure 5: Div's C,D Inbound scatterometer integration in target body-fixed coordinates

at the specified maximum rate of 90.0 Kbps, the remaining 81.6 Mbits will last for 6.8 min. The actual numbers in the IEB will be a little different to accomodate all the instrument and viewing geometry timing constraints.

The main consideration for distant scatterometer integrations is the time and data volume needed for a detection. The detection calculation is summarized in a separate memo [distant scatterometer detection memo - this will be updated and expanded]. Figure 4 shows the range variation during the inbound observation, while Fig's 6 and 7 shows the associated integration time and data volume needed for a single point detection. The system parameters used in the detection calculations for divisions C and D are listed below. The primary consideration is collecting as much signal energy as possible. Therefore, the IEB is set at a high pulse duty cycle of 0.7, and as close as possible to the maximum transmit duty cycle of 0.069.

System parameters for division C:

- $P_t = 46 \text{ W}$
- $T_{sys} = 1000 \text{ K}$
- $G_{antenna} = 50.7 \text{ dB}$
- frequency = 13.78 GHz
- beamwidth = 0.35 deg
- PRF = 1200 Hz
- pulse width = 583.3 us
- burst period = 1592.6 ms
- bursts in flight = 1
- burst duty cycle = 0.03

System parameters for division D:

- $P_t = 46 \text{ W}$
- $T_{sys} = 1000 \text{ K}$
- $G_{antenna} = 50.7 \text{ dB}$
- frequency = 13.78 GHz

Name	Nominal	c	d	Mismatch	Comments
mode	scatterometer	scatterometer	scatterometer	no	
start_time (min)	varies	-248.0	-246.0	no	
end_time (min)	varies	-246.0	-240.0	no	
time_step (s)	don't care	10.0	16.0	no	Used to set instruction valid time for radiometer and scatterometry with multiple bursts in flight
bem	00100	00100	00100	no	
baq	5	5	5	no	
csr	0	8	0	yes	0 - Normal Operation, 8 - with auto-gain
noise_bit_setting	4	4	4	no	Scat signal set higher than ALT/SAR
dutycycle	0.70	0.70	0.70	no	
prf (KHz)	varies	1.20	4.00	no	Set to cover target doppler bandwidth
number_of_pulses	varies	80	200	no	depends on PRF choice (can have more shorter pulses)
n_bursts_in_flight	varies	1	2	no	Used to increase PRF and data rate at long range
percent_of_BW	0.0	0.0	0.0	no	
auto_rad	on	on	on	no	
rip (ms)	34.0	34.0	34.0	no	
max_data_rate	200.000	90.000	200.000	yes	Kbps, restricted by one burst in flight
interleave_flag	off	off	off	no	
interleave_duration (min)	don't care	1.5	10.0	no	

Table 5: PH div_cd distant_scatterometer block

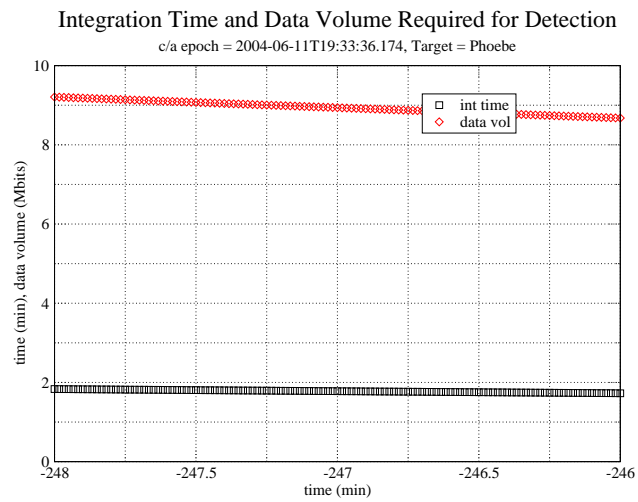


Figure 6: Inbound scatterometry Div C: Detection integration time required for a single point detection using optimal chirp bandwidth

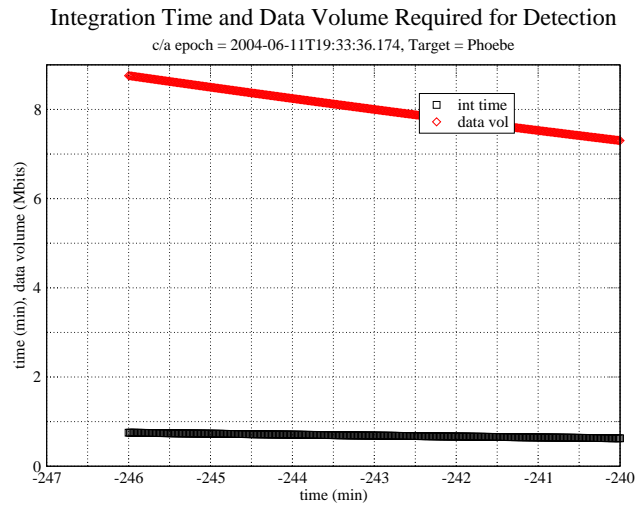


Figure 7: Inbound scatterometry Div D: Detection integration time required for a single point detection using optimal chirp bandwidth

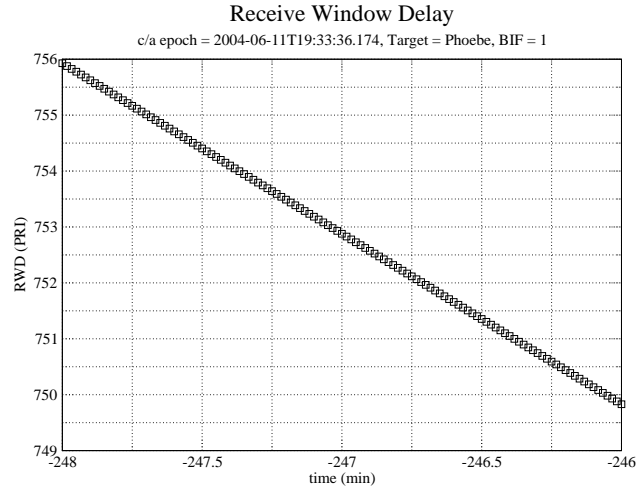


Figure 8: Div C Inbound scatterometer receive window delay

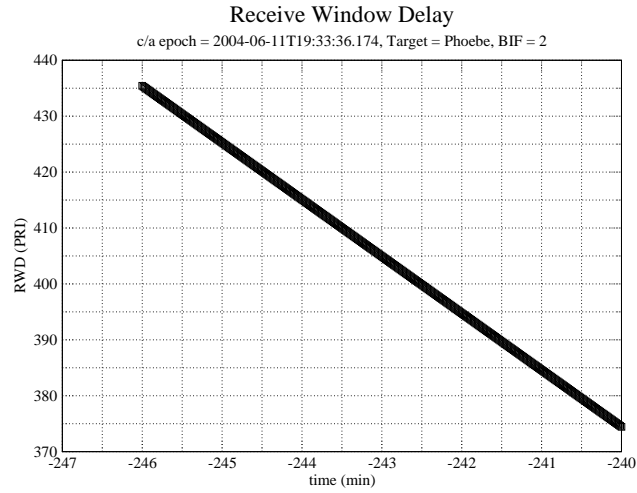


Figure 9: Div D Inbound scatterometer receive window delay

- beamwidth = 0.35 deg
- PRF = 4000 Hz
- pulse width = 175.0 us
- burst period = 515.0 ms
- bursts in flight = 2
- burst duty cycle = 0.07

4.2.1 PRF and Burst Interleaving

The relatively high PRF specified for division D in Table 5 poses a special problem. The receive window delay used to position the echo window within each burst is set to a particular number of pulse repetition intervals (PRI) after the start of the pulse transmission. When the PRI is very small, then the round trip time to the target can exceed the

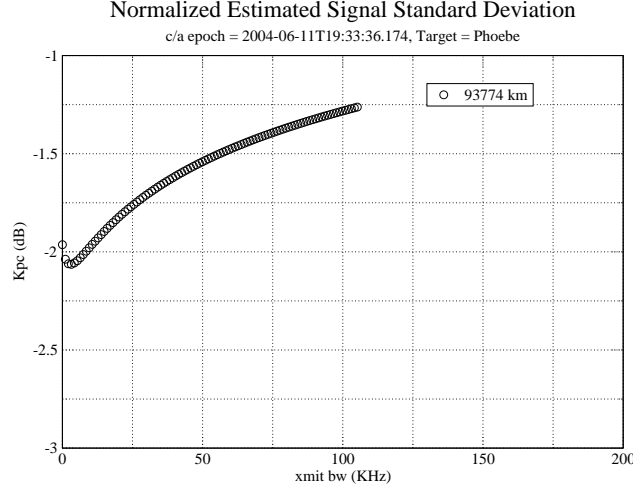


Figure 10: Inbound observation Div C: Disk integrated normalized estimated signal standard deviation at minimum range, and 15 minutes away from minimum range (if present).

maximum allowed receive window delay ($1023 \cdot \text{PRI}$). This problem occurs for Phoebe, so burst interleaving is needed to accomodate the high PRF. Burst interleaving is also needed to maintain a high data rate which relies on the short burst period allowed by the high PRF.

In division C, only one burst in flight is allowed, and this limits the PRF to be less than about 1.6 KHz. The variation of receive window delay (RWD) is shown in Fig's 8 and 9 for divisions C and D respectively.

4.2.2 Chirp bandwidth and PRF

When the signal strength is high enough to produce a relatively short detection time and data volume (compared to available time and data volume) then choices of chirp bandwidth and PRF that will make range filtering possible can be considered. Filtering both range and doppler using pulse compression and spectral filtering requires the PRF to be larger than the doppler bandwidth of the target. Otherwise, it would be impossible to perform doppler filtering after pulse compression because the doppler spectrum of the target would be aliased (folded over itself). Phoebe is not tidally locked. Using a rotation period of 9 hr, the target doppler bandwidth is 3802 Hz.

Fig's 10 and 11 show how detection performance varies with chirp bandwidth for divisions C and D of the inbound observation. The detection time is the integration time needed to reduce the estimated signal standard deviation to 1/10 the expected value. For optimal detection performance, the chirp bandwidth should be set to the minimum K_{pc} point. K_{pc} is the normalized standard deviation of the estimated signal energy. For a single pulse, K_{pc} is given by,

$$K_{pc}^2 = \frac{1}{B_s \tau_p} + \frac{2}{\text{SNR} B_s \tau_p} + \frac{1}{\text{SNR}^2 B_s \tau_p}, \quad (1)$$

where B_s is the signal bandwidth, τ_p is the pulse length, and SNR is the signal to noise ratio using the incidence angle dependent backscatter model shown in Fig. 12 and integrating the radar equation. Summing all the pulses from all the bursts reduces the measurement variance by the number of pulses summed,

$$K_{pcdisk}^2 = \frac{1}{N_p N_b} K_{pc}^2 \quad (2)$$

where N_p is the number of pulses per burst, and N_b is the number of bursts summed together. Using a single value of -10 dB for σ_0 only causes a few tenths of a dB change in the final disk integrated K_{pc} . In cases where there is signal to spare (very small detection times), a larger chirp bandwidth can be selected to allow for pulse compression and range filtering. There will be a tradeoff between the quality of each range/doppler "pixel", and the number or resolution of these pixels. The minimum K_{pc} point for the inbound observation is close to zero chirp bandwidth. Transmitting a finite chirp bandwidth would allow for range filtering at the expense of higher estimated signal variance. For divisions

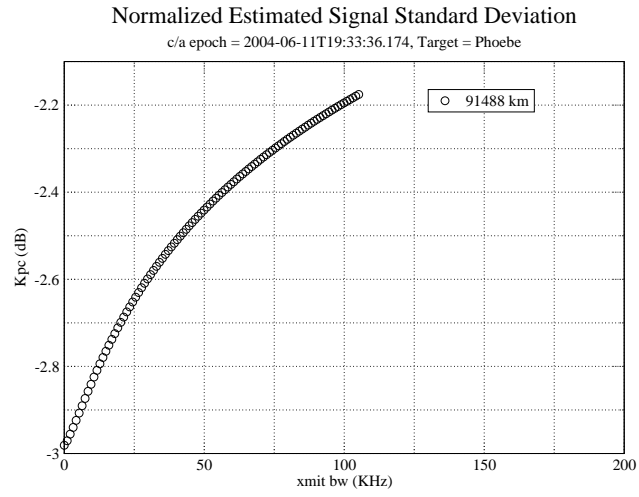


Figure 11: Inbound observation Div D: Normalized estimated signal standard deviation for a disk integrated observation assuming all the bursts occur at minimum range, and 15 minutes away from minimum range.

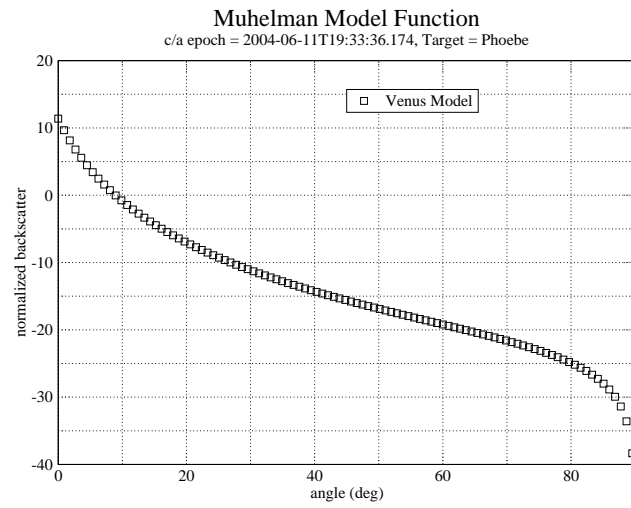


Figure 12: Backscatter model function used to evaluate radar performance.

Name	Nominal	Actual	Mismatch	Comments
mode	radiometer	radiometer	no	
start_time (min)	varies	-240.0	no	
end_time (min)	varies	140.0	no	
time_step (s)	2700.0	1800.0	yes	
bem	00100	00100	no	
baq	don't care	5	no	
csr	6	6	no	
noise_bit_setting	don't care	4	no	
dutycycle	don't care	0.38	no	
prf (KHz)	don't care	1.00	no	
number_of_pulses	don't care	8	no	
n_bursts_in_flight	don't care	1	no	
percent_of_BW	don't care	100.0	no	
auto_rad	on	on	no	
rip (ms)	34.0	34.0	no	
max_data_rate	0.250	0.250	no	
interleave_flag	off	off	no	
interleave_duration (min)	don't care	10.0	no	

Table 6: PH div_e radiometer_fill block

C and D, there is not enough spare performance to consider range filtering, so the transmitted chirp is set to zero bandwidth.

When range filtering is used, the un-aliased doppler bandwidth is reduced to the PRF. This means that tracking the doppler centroid will be a potential issue for processing the data. Without doppler filtering, the doppler bandwidth equals the full complex sample rate (ie., half the ADC rate), and the processing then has more latitude to search for the signal.

4.2.3 Noise Only Data and Timing Considerations

When a tone is transmitted, there is no need to schedule noise only bursts using the interleaving option in RMSS. Spectral extraction of the target will leave a large portion of the scatterometer filter bandwidth (117 KHz) available to form a noise only estimate for every burst. Hence this option is "off" for divisions C and D. The scatterometer mode uses a transmit receive window offset (TRO) of 6 which means that every burst will have 6 PRI's of noise only time in the echo window. If the ephemeris accuracy is good enough, then these noise only PRI's can also be identified and used as noise only data.

There is a possibility of having noise only bursts when there are multiple bursts in flight. This occurs at instruction boundaries which are inserted to track changing range and doppler. Instruction boundaries are required to fall on one-second ticks, and depending on the timing parameters, there may be a non-integer number of burst periods within each instruction time. For division D, the current parameters work out very tightly with 4 msec of dead time between instructions. Since the echo windows are about 50 msec long, most of the pulses will still be captured.

5 Non-RADAR Interval - 2nd IEB, Div E

At the end of the inbound scatterometry the telemetry mode will switch to the ORS instruments. RADAR will remain powered on in warmup2 state to keep the Radio Frequency Electronics System (RFES) stable for the outbound observation. No data will be collected during this interval which starts at 2004-06-11T18:33:37.000 (-00:59:59.2) and lasts for 03:00:0.0. Phoebe closest approach occurs at 2004-06-11T19:33:36.174. The IEB during this invisible time is set to slow rate radiometry as shown in Table 6.

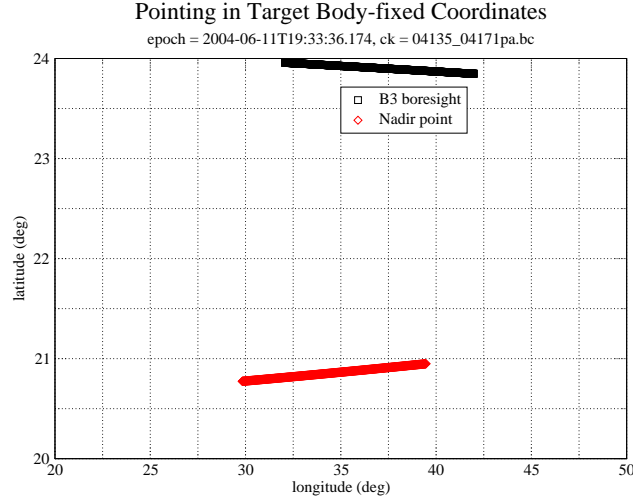


Figure 13: Div's F,G,H Outbound scatterometer integration in target body-fixed coordinates

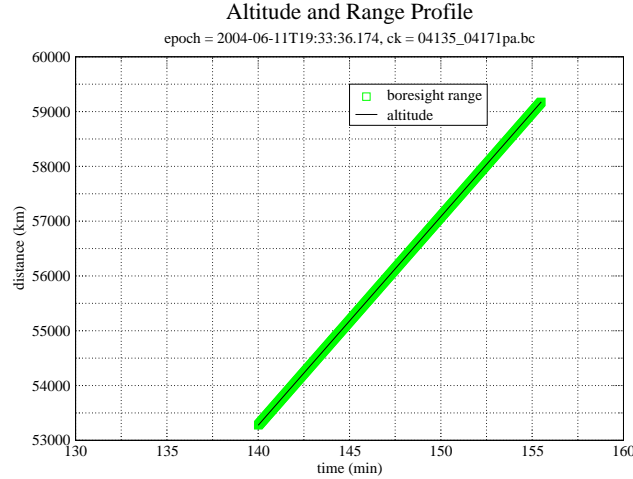


Figure 14: Outbound scatterometry: range to target nadir point

6 Outbound Phoebe Distant Scatterometry/Radiometry - 2nd IEB

The outbound observation starts at 2004-06-11T21:33:37.000 (02:00:0.8) with a duration of 04:15:0.0. The remainder of the data volume (200 Mbits) is allocated to this observation.

The recommended pointing strategy was to target the center of Phoebe at the beginning of the observation and stare at it for the first 2 hours, then execute two radiometer raster scans centered on Phoebe (with scans like the 1st observation). Following the raster, the spacecraft goes back to staring at the center of Phoebe for the remaining time. The scatterometer integration is located at the beginning of the observation when the signal is strongest. Using the division F specified maximum rate of 0.2 Kbps, the 200 Mbits will occupy 16.7 min.

6.1 Outbound Scatterometry - Div's F,G,H

Figure 13 shows the pointing design for divisions F,G and H from the merged ckernel. The range variation to the target for the outbound scatterometer integration is shown in Fig. 14. The associated detection integration time and data volume is shown for the F, G, and H divisions in Figs. 15, 16, 17. The IEB instructions for this outbound

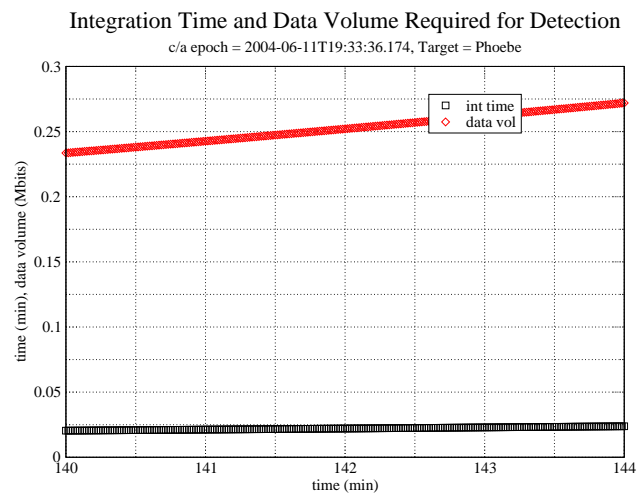


Figure 15: Outbound scatterometry, Div F: Detection integration time required for a single point detection using optimal chirp bandwidth

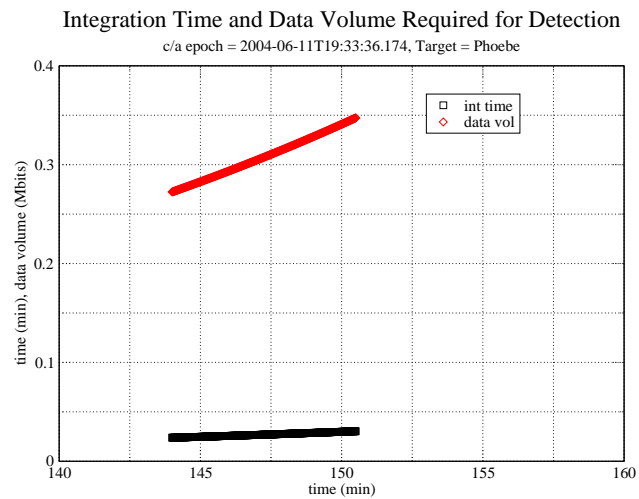


Figure 16: Outbound scatterometry, Div G: Detection integration time required for a single point detection using optimal chirp bandwidth

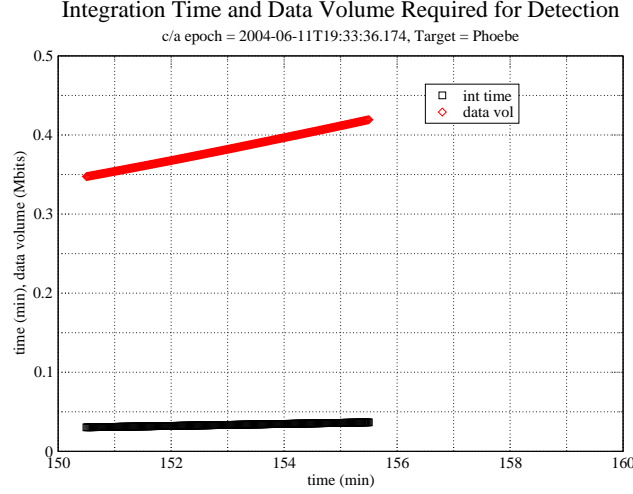


Figure 17: Outbound scatterometry, Div H: Detection integration time required for a single point detection using optimal chirp bandwidth

scatterometry block are generated by RMSS under the control of the set of config parameters in block's F, G, and H as shown in Table 7

6.1.1 Chirp bandwidth and PRF

Figure 19 shows how detection performance varies with chirp bandwidth over the time of division F. For optimal detection performance, the chirp bandwidth should be set to the minimum K_{pc} point. Like the inbound case, the outbound case has a minimum variance with zero chirp bandwidth. However, the outbound case has better performance (lower K_{pc}) than the inbound case because the range is about half as large. The penalty for transmitting a full chirp is about 0.5 dB of increased K_{pc} for the disk integrated result. Given the much reduced detection time, the outbound divisions are much more likely to allow range and doppler filtering. For this reason, divisions F and G are set to the nominal scatterometer chirp bandwidth (106 KHz) to permit range filtering at the expense of 0.5 dB of increased K_{pc} . Division F uses 4 KHz PRF while division G uses 4.5 KHz PRF. The PRF step is implemented to provide some ability to resolve range ambiguities. At a 4 KHz PRF, range ambiguities are spaced at 38 km intervals. Phoebe has a radius of 110 km, so there will be range ambiguities to contend with.

Division H is set for 5 minutes of tone transmission (no chirp) just like the inbound divisions C and D. This provides a core data set that will be collected always with a tone and can be easily compared with other segments that are also collected with tone transmission. Figure ?? shows the K_{pc} performance prediction for the time of division H.

As with the inbound case, multiple bursts in flight are needed to support a high PRF and a high data rate. Figure 20 shows the RWD plot for division F.

6.2 Outbound Radiometry - Div's I,J,K

The remainder of the outbound observation is for radiometry. Three divisions cover this time. Division I covers the last part of the outbound stare used by the scatterometer integration. Division J covers the two radiometer raster scans. Division J is set so that it picks up a auto-rad setting while beam 3 is on the target body, and then uses it throughout the scans. Division K covers the final outbound radiometer stare. Figure 21 shows the range/altitude variation during the scans. One of the scans is shown in Figure 22 from the merged ckernel. The boresight is pointed off target most of the time, hence the range/altitude plot shows only a few boresight range points. Like the inbound scan, these scans use 1/4 beamwidth spacing to allow for some super-resolution processing of the radiometer data. The angular size of the target is about 2.0 mrad during the scans, while the beam 3 beamwidth is 6 mrad, so radiometer resolution will be limited. The division parameters are shown in Tables 8 through 10.

Name	Nominal	f	g	h	Mismatch	Comments
mode	scatterometer	scatterometer	scatterometer	scatterometer	no	
start_time (min)	varies	140.0	144.0	150.5	no	
end_time (min)	varies	144.0	150.5	155.5	no	
time_step (s)	don't care	16.0	16.0	16.0	no	Used to set instruction valid time for radiometer and scatterometry with multiple bursts in flight
bem	00100	00100	00100	00100	no	
baq	5	5	5	5	no	
csr	0	0	0	0	no	0 - Normal Operation, 8 - with auto-gain
noise_bit_setting	4	4	4	4	no	Scat signal set higher than ALT/SAR
dutycycle	0.70	0.70	0.70	0.70	no	
prf (KHz)	varies	4.00	4.50	4.00	no	Set to cover target doppler bandwidth
number_of_pulses	varies	120	120	120	no	depends on PRF choice (can have more shorter pulses)
n_bursts_in_flight	varies	2	2	2	no	Used to increase PRF and data rate at long range
percent_of_BW	0.0	100.0	100.0	0.0	yes	
auto_rad	on	on	on	on	no	
rip (ms)	34.0	34.0	34.0	34.0	no	
max_data_rate	200.000	200.000	200.000	200.000	no	Kbps - determines burst period
interleave_flag	off	off	off	off	no	
interleave_duration (min)	don't care	3.0	10.0	10.0	no	

Table 7: PH div_fgh distant_scatterometer block

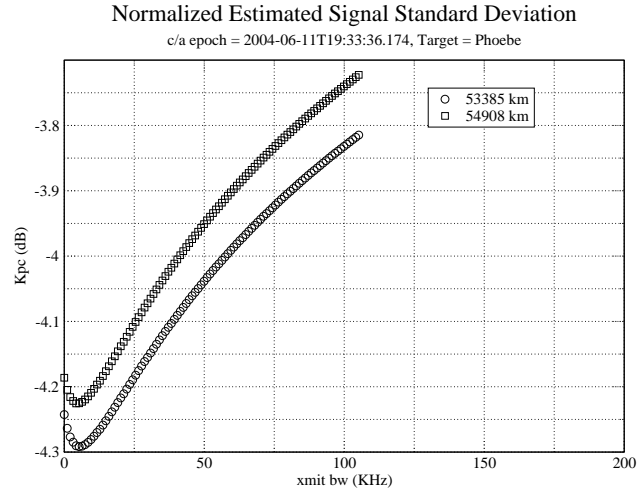


Figure 18: Outbound scatterometry Div F: Normalized estimated signal standard deviation for a disk integrated observation assuming all the bursts occur at minimum range, and 15 minutes away from minimum range.

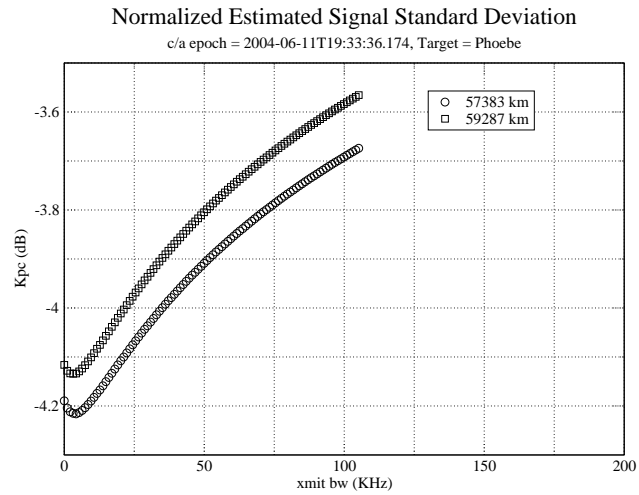


Figure 19: Outbound scatterometry Div H: Normalized estimated signal standard deviation for a disk integrated observation assuming all the bursts occur at minimum range, and 15 minutes away from minimum range.

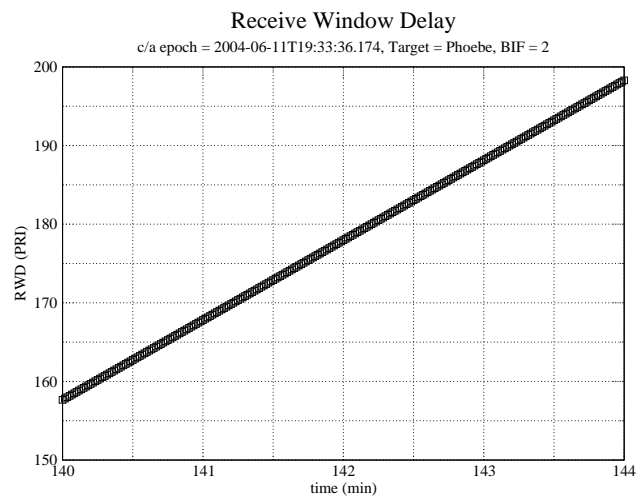


Figure 20: Outbound scatterometer receive window delay

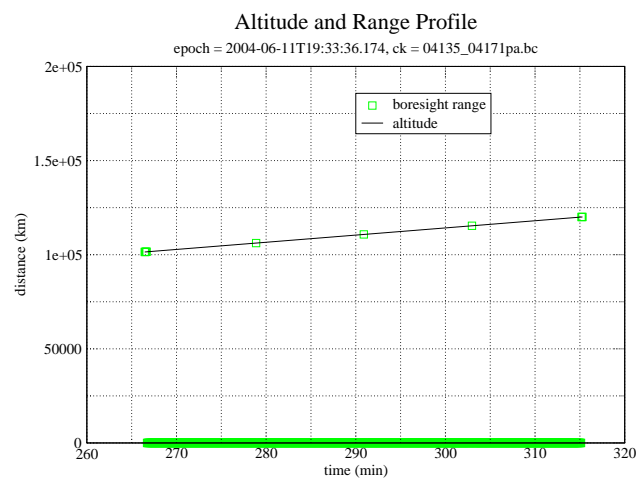


Figure 21: Outbound radiometry: range to target nadir point during scans

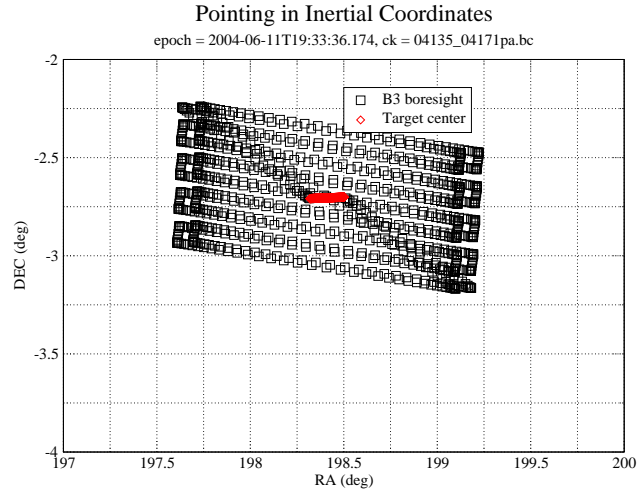


Figure 22: One outbound scan in inertial coordinates

Name	Nominal	Actual	Mismatch	Comments
mode	radiometer	radiometer	no	
start_time (min)	varies	155.5	no	
end_time (min)	varies	265.0	no	
time_step (s)	varies	900.0	no	Used by radiometer only modes
bem	00100	00100	no	
baq	don't care	5	no	
csr	6	6	no	
noise_bit_setting	don't care	4	no	
dutycycle	don't care	0.38	no	
prf (KHz)	don't care	1.00	no	
number_of_pulses	don't care	8	no	
n_bursts_in_flight	don't care	1	no	
percent_of_BW	don't care	100.0	no	
auto_rad	on	on	no	
rip (ms)	34.0	34.0	no	starting value for auto-rad
max_data_rate	1.000	1.000	no	1 Kbps - 1 s burst period which is adequate for slow radiometer scans
interleave_flag	off	off	no	
interleave_duration (min)	don't care	10.0	no	

Table 8: PH div_i distant_radiometer block

Name	Nominal	Actual	Mismatch	Comments
mode	radiometer	radiometer	no	
start_time (min)	varies	265.0	no	
end_time (min)	varies	317.0	no	
time_step (s)	varies	3600.0	no	Used by radiometer only modes
bem	00100	00100	no	
baq	don't care	5	no	
csr	6	6	no	
noise_bit_setting	don't care	4	no	
dutycycle	don't care	0.38	no	
prf (KHz)	don't care	1.00	no	
number_of_pulses	don't care	8	no	
n_bursts_in_flight	don't care	1	no	
percent_of_BW	don't care	100.0	no	
auto_rad	on	on	no	
rip (ms)	34.0	34.0	no	starting value for auto-rad
max_data_rate	1.000	1.000	no	1 Kbps - 1 s burst period which is adequate for slow radiometer scans
interleave_flag	off	off	no	
interleave_duration (min)	don't care	10.0	no	

Table 9: PH div_j distant_radiometer block

Name	Nominal	Actual	Mismatch	Comments
mode	radiometer	radiometer	no	
start_time (min)	varies	317.0	no	
end_time (min)	varies	400.0	no	
time_step (s)	varies	1800.0	no	Used by radiometer only modes
bem	00100	00100	no	
baq	don't care	5	no	
csr	6	6	no	
noise_bit_setting	don't care	4	no	
dutycycle	don't care	0.38	no	
prf (KHz)	don't care	1.00	no	
number_of_pulses	don't care	8	no	
n_bursts_in_flight	don't care	1	no	
percent_of_BW	don't care	100.0	no	
auto_rad	on	on	no	
rip (ms)	34.0	34.0	no	starting value for auto-rad
max_data_rate	1.000	0.500	yes	1 Kbps - 1 s burst period which is adequate for slow radiometer scans
interleave_flag	off	off	no	
interleave_duration (min)	don't care	10.0	no	

Table 10: PH div_k distant_radiometer block